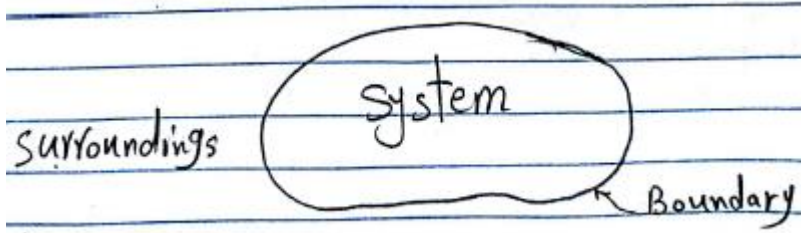
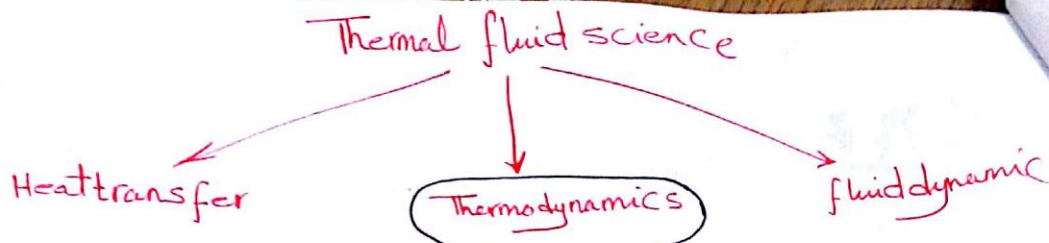


Ch (1) : Introduction

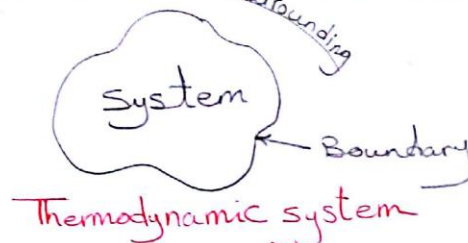
Thermodynamics :	Science deals with mechanical energy and heat and conversion between each other -engineering tool to describe process that involve change in temperature transform energy (heat and work)
System :	It's a quantity of matter or a region in space chosen for study
Surroundings	It's a region outside the system
Boundary	It's a real or imaginary surface that separate the surface from it's surroundings 
Control Volumes	It's a region in space separated from it's surrounding by a real or imaginary boundary " the control surface " across which mass may pass



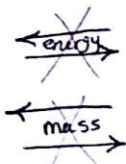
Heat & Mechanical energy.
Heat & Work
change in Temp.
Transformation of energy.

- * Application of Thermodynamics $\equiv$
- * Classification of energy $\equiv$
- * Energy sources $\equiv$
- * Type of power plants $\equiv$

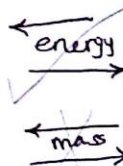
- * Control Volume & surface
- * Thermal equilibrium
- * Mechanical equilibrium
- * phase equilibrium
- * chemical equilibrium



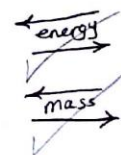
isolated



closed



open



Properties per unit mass called specific

intensive: Does not depend on mass

Extensive: Depend on mass

Process

Reversible: go back to initial in reverse direction along the same Path, Heat. wouldn't happen in real

irreversible: go back to initial with reverse process
Some changes happen to the sys.

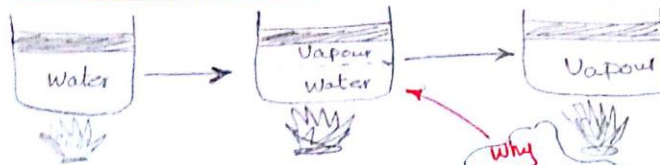
→ **Isothermal process**, **Isobaric process**, **Isometric process**

→ **Thermodynamic cycle:** sequence of process in which working fluid returns to its original thermo... state.

→ **Zeroth Law of thermo...** : $A=B, B=C \rightarrow A=C$

→ $1 \text{ Pa} = 1 \text{ N/m}^2 \rightarrow 1 \text{ bar} = 10^5 \text{ Pa} = .1 \text{ MPa} = 100 \text{ kPa}$

** pressure measurement



- Compressed Liquid or subcooled
- Saturated liquid
- Saturated Vapor
- Saturated liquid-Vapor mixture
- Super heated Vapor

all most all power plants use the conversion of liquid to gas to generate power

** The difference between saturated vapor & super heated

$$T \uparrow \rightarrow m_{\text{const}} \rightarrow U \uparrow$$

* At a given Temp. The pressure which sub. changes phase $\rightarrow P_{\text{sat}}$

* At a given P The Temp which sub. changes phase $\rightarrow T_{\text{sat}}$

→ Latent heat: ~~the~~ energy absorbed during vaporization and is equal to energy released during condensation.

→ Critical point: point at which the saturated liquid and saturated vapor states are identical.

^{water} Critical point properties / $P_{\text{cr}} = 22.06 \text{ MPa}$ $T_{\text{cr}} = 373.95^\circ\text{C}$ $V_{\text{cr}} = 0.003106 \text{ m}^3/\text{kg}$

→ Quality / Dryness factor within any place inside the wet region $= \frac{m_g}{m_t} = \frac{V - V_f}{V_{fg}}$: $f \rightarrow \text{Liquid}$ $g \rightarrow \text{Vapor}$
 $V_{fg} = V_g - V_f$

$$\boxed{V = V_f + x V_{fg}}$$

P-V diagram with solid phase $\rightarrow ??$

Tripple point $\rightarrow$ liquid-gas-solid

→ $h = u + PV$ or $H = U + PV$

$$V = V_f + V_g, \quad V = m v$$

$$m_t v = m_f V_f + m_g V_g \rightarrow m_t V = (m_t - m_g) V_f + m_g V_g$$

$$V = (1-x) V_f + x V_g \rightarrow \boxed{V = V_f + x V_{fg}}$$

$$\boxed{u = u_f + x u_{fg}}$$

$$\boxed{h = h_f + x h_{fg}}$$

$$\div m_t$$

① wet steam, $x = \%$ $\rightarrow$ given

② $m_g, m_f \rightarrow x = \frac{m_g}{m_t}$

③ P or T given with V

From table $V_f = v$ $V_g = v$

if $V > V_g$ $\rightarrow$ wet steam

$$\text{so } V = V_f + x(V_g - V_f) \rightarrow \text{so } x =$$

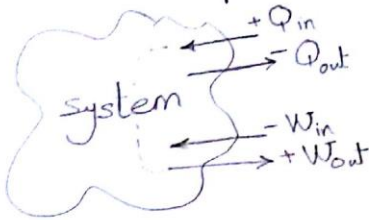
④ P or T given with V & m $\rightarrow V = \frac{V}{m} \rightarrow$ ③ find x

→ First Law of thermodynamics: الطاقة لا تفنى ولا تستحدث من لا شيء بل تتحول من صورة الى اخرى

→ In any process of a closed system the energy of the system increases or decreases by an amount equal to the net amount of energy transferred across its boundary.

→ Energy balance: $Q_{net} - W_{net} = \Delta U$

→ Adiabatic process → heat transfer is zero



→ In General case: $W = \int_1^2 P dV$, $dU = \overset{\text{specific}}{u_2 - u_1}$

→ For ideal gases

$$\Delta U = U_2 - U_1 = \int_1^2 C_v(T) dT \approx C_{v,av} (T_2 - T_1)$$

$$\Delta h = h_2 - h_1 = \int_1^2 C_p(T) dT \approx C_{p,av} (T_2 - T_1)$$

$$R = C_p - C_v$$

→ Forms of work

• Electrical $W_e = VI \Delta t$

• Boundary $W_b = \int_1^2 P dV$

• Gravitational $W_g = mg(z_2 - z_1)$

• Acceleration $W_a = \frac{1}{2} m (\bar{V}_2^2 - \bar{V}_1^2)$

• shaft $W_{sh} = 2\pi n t$

• Spring $W_{spring} = \frac{1}{2} K (x_2^2 - x_1^2)$

Water
 $C_p = 4.18 \text{ kJ/kg} \cdot ^\circ\text{C}$
 $\rho = 1000$

Air
 $C_p = 1.005 \text{ kJ/kg} \cdot ^\circ\text{C}$

$C_v = 0.718$

$\beta = 1.2$

$R = 0.287$

$PV = mRT$
 $P = \rho R T$ } Air

$W_{net} = W_{net, other} + W_b$

Applications:

$V = \text{const}$

$W = 0$

$\Delta U = Q$

$U_2 - U_1 = Q$

$P = \text{const}$

$W = P(V_2 - V_1)$

$H = U + PV$

$Q = m(h_2 - h_1)$

$Q = P(V_2 - V_1)$

$+ U_2 - U_1$

Adiabatic

$Q = \text{Zero}$

$-W = U_2 - U_1$

Isothermal
 $T = \text{const}$

$PV_1 = P_2V_2$

$= PV = C$

$W = P_2V_2 \ln\left(\frac{V_2}{V_1}\right)$

Polytropic

$PV^n = \text{const}$

$W_b = C \frac{(V_2^{-n+1} - V_1^{-n+1})}{1-n}$

$W = \frac{P_1V_1 - P_2V_2}{n-1}$

$W = \frac{mR(T_2 - T_1)}{1-n}$

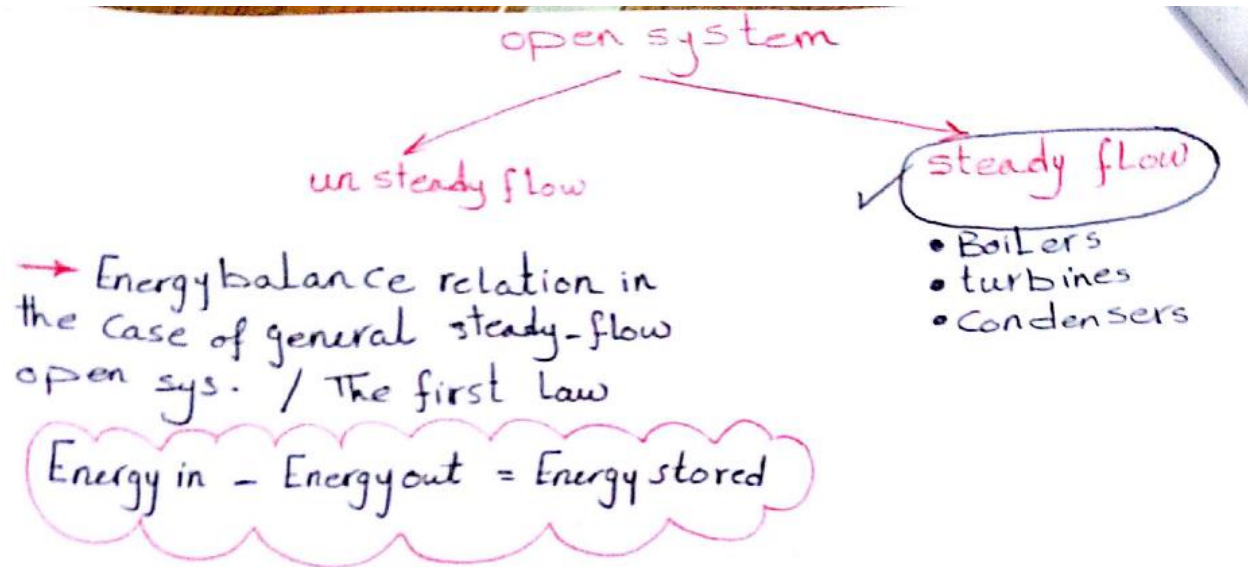
$W = \frac{P_2V_2 - P_1V_1}{1-n}$

$$Pv = RT$$

$$h = u + Pv = u + RT$$

$$R = C_p - C_v = 0.278 \text{ kJ/kg.k}$$

$$\gamma = \frac{C_p}{C_v} = 1.4 \text{ for air}$$



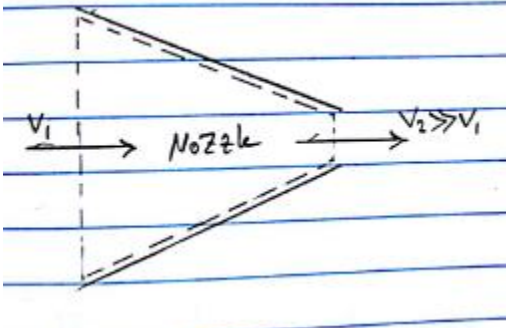
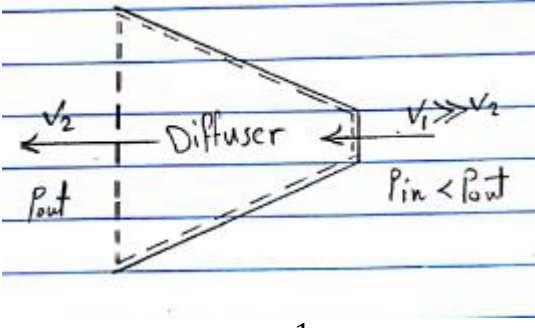
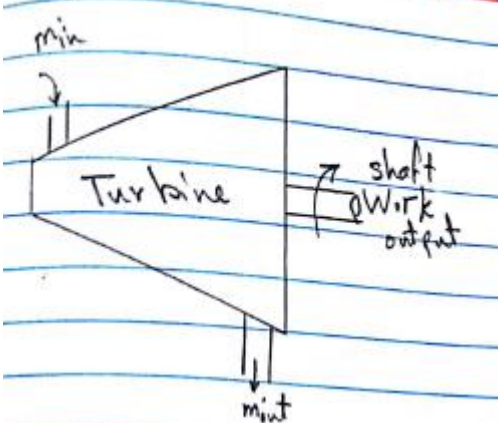
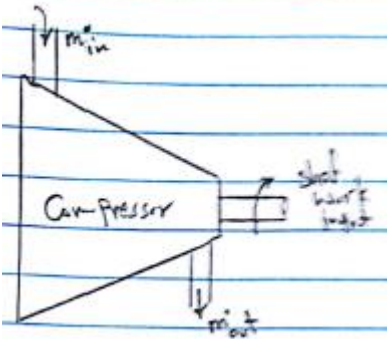
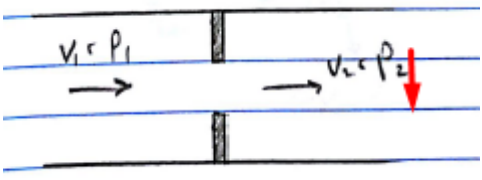
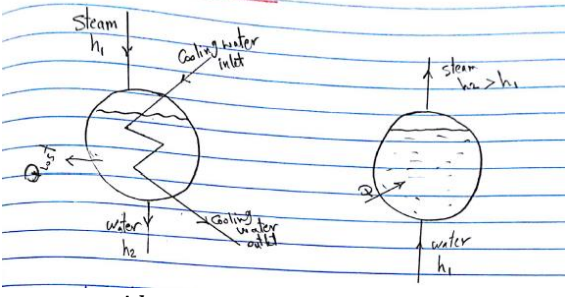
Open system : Steady flow : Energy balance

$$Q_{in} + W_{in} + m_{in} \left(u_1 + P_1 v_1 + \frac{v_1^2}{2} + g z_1 \right) - Q_{out} - W_{out} - m_{out} \left(u_2 + P_2 v_2 + \frac{v_2^2}{2} + g z_2 \right) = \Delta E$$

For steady flow and dividing by $\dot{m}$

$$q - w = h_2 - h_1 + \frac{v_2^2 - v_1^2}{2} + g(z_2 - z_1)$$

Devices :

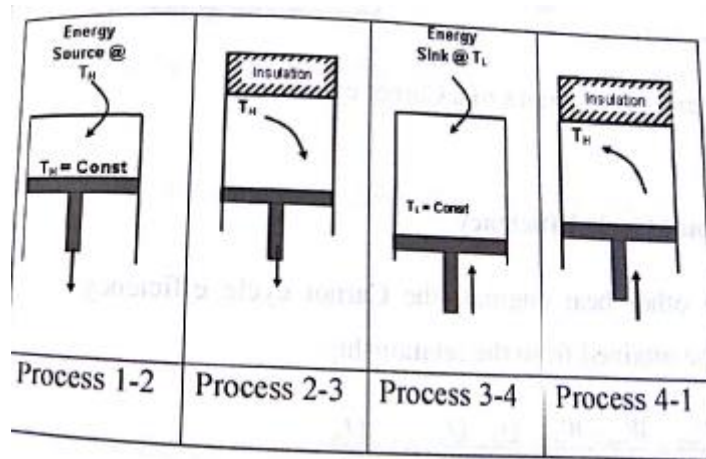
Nozzle  $h_2 - h_1 = \frac{1}{2}(v_2^2 - v_1^2)$	Diffuser  $h_2 - h_1 = \frac{1}{2}(v_2^2 - v_1^2)$
Turbine  $W(+ve) = \Delta h$ $\Delta h = C_p(T_2 - T_1)$	Compressor  $W(-ve) = \Delta h$ $\Delta h = C_p(T_2 - T_1)$
Throttling valve  $h_1 = h_2$ $u_1 + p_1 v_1 = u_2 + p_2 v_2$	Condenser & Boiler  $q = \Delta h$ $q_{\text{steam}} = q_{\text{cooling water}} + q_{\text{lost if found}}$

GAS CYCLE (1) Otto cycle

Carnot (Perfect) cycle principles

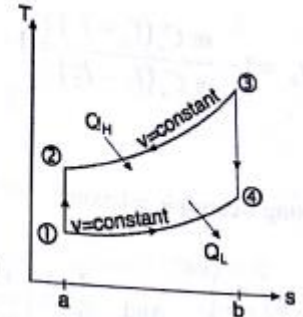
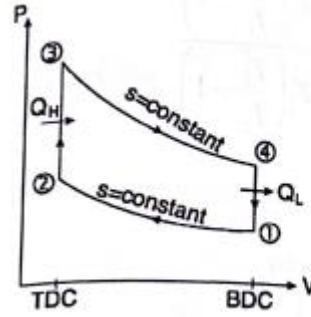
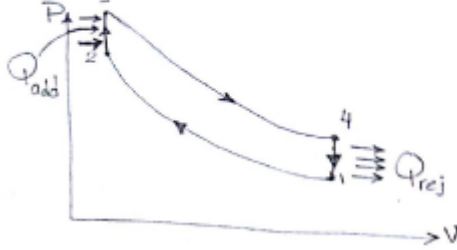
- 1- The efficiency of an irreversible heat engine is always less than the efficiency of a reversible one operating between the same two reservoirs
- 2- The efficiencies of all reversible heat engines operating between the same two reservoirs are the same

$$3- \eta = 1 - \frac{Q_L}{Q_H} = 1 - \frac{T_L}{T_H}$$



(1) Gas CYCLE

① Otto cycle



(1-2) Isentropic Compression	(2-3) constant volume heat addition	(3-4) Isentropic Expansion	(4-1) constant volume heat rejection
$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$	$\begin{aligned} V_2 &= V_3 \\ \frac{P_2}{T_2} &= \frac{P_3}{T_3} \\ q_{add} &= c_v(T_3 - T_2) \end{aligned}$	$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_4}{V_3}\right)^{\gamma-1}$	$\begin{aligned} V_4 &= V_1 \\ \frac{P_4}{T_4} &= \frac{P_1}{T_1} \\ q_{rej} &= c_v(T_4 - T_1) \end{aligned}$

$$r = \frac{V_1}{V_2} = \frac{V_4}{V_3} = \frac{\text{Max Volume}}{\text{Min Volume}} \quad (\text{compression ratio})$$

$$W_{net} = Q_{add} - Q_{rej} \text{ (kJ)} = \text{MEP} \times \text{Piston area} \times \text{stroke} \\ = \text{MEP} \times \text{displacement volume}$$

$$w_{net} = q_{add} - q_{rej} \text{ (kJ/kg)}$$

$$\eta_{thotto} = \frac{W_{net}}{Q_{add}} = 1 - \left(\frac{1}{r}\right)^{\gamma-1}$$

$$\text{MEP} = \frac{W_{net}}{V_1 - V_2} = \frac{\text{network output}}{\text{stroke volume}} \quad \left(\frac{\text{kJ}}{\text{m}^3}\right)$$

Given: $P_1, T_1, \gamma, q_{add}$
or max Tem. (T_3)

Req: Thermal efficiency
: Mean effective pressure (MEP)

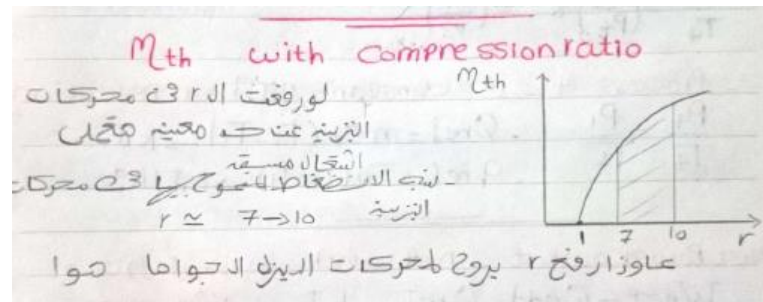
$$\text{MEP} = \frac{\text{net work output}}{\text{stroke volume}} = \frac{W_{net}}{V_1 - V_2} \quad \left(\frac{\text{kJ}}{\text{m}^3}\right) \\ = \frac{\text{KN}}{\text{m}^2} = \text{KPa}$$

if W_{net} (kJ/kg) so V must be specific Vol. $\text{m}^3/\text{kg} \rightarrow \text{MEP} = \text{KPa}$

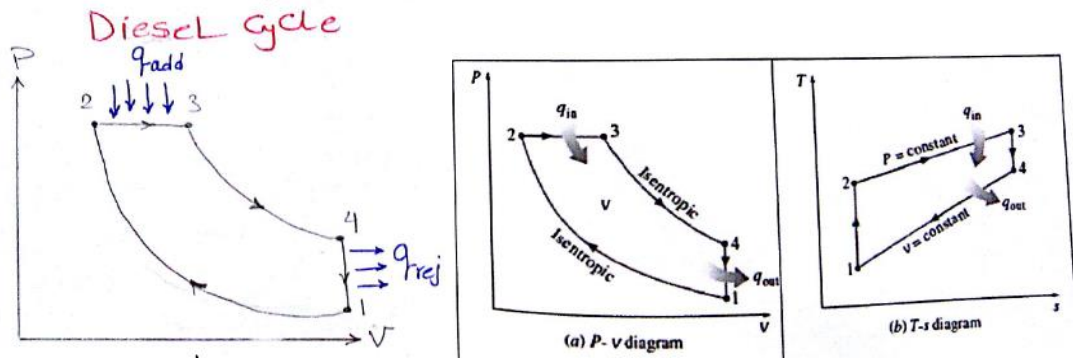
$$PV = RT \quad R = c_p - c_v = 0.287 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$$

$$PV_1 = RT_1 \quad PV_2 = RT_2 \quad \rightarrow \text{if } T_1, T_2 \text{ are known, then } P_1, P_2 \text{ can be found}$$

$$\begin{aligned} \eta_{otto} &= \frac{W_{net}}{Q_{add}} = \frac{Q_{add} - Q_{rej}}{Q_{add}} = 1 - \frac{Q_{rej}}{Q_{add}} \\ &= 1 - \frac{m c_v (T_4 - T_1)}{m c_v (T_3 - T_2)} = 1 - \frac{T_1}{T_2} \frac{(T_4/T_1 - 1)}{(T_3/T_2 - 1)} = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \\ \therefore \frac{T_1}{T_2} &= \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{1}{r}\right)^{\gamma-1} \\ \therefore \frac{T_4}{T_1} &= \frac{T_4}{T_3} \cdot \frac{T_3}{T_2} \cdot \frac{T_2}{T_1} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} \cdot \frac{T_3}{T_2} \cdot \left(\frac{V_1}{V_2}\right)^{\gamma-1} = \frac{T_3}{T_2} \end{aligned}$$



(2) Diesel CYCLE



عند رفع ال r عن حد معين يحصل اشتعال ذاتي ، فهنخلي الشحنة بس ونستخدم محركات diesel

(1-2) Isentropic compression	(2-3) constant pressure heat addition [combustion]	(3-4) isentropic expansion	(4-1) constant volume heat rejection
$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (r)^{\gamma-1}$	$\begin{aligned} P_2 &= P_3 \\ V_2 &= V_3 \\ \frac{T_2}{T_3} &= \frac{T_3}{T_3} \\ q_{add} &= C_p(T_3 - T_2) \left(\frac{kJ}{kg}\right) \end{aligned}$	$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_4}{V_3}\right)^{\gamma-1}$	$\begin{aligned} V_4 &= V_1 \\ \frac{P_4}{T_4} &= \frac{P_1}{T_1} \\ q_{rej} &= C_v(T_4 - T_1) \end{aligned}$

$$r = \frac{V_1}{V_2} \text{ compression ratio}$$

$$r_c = \frac{V_3}{V_2} = \frac{\text{vol. before combustion}}{\text{vol after combustion}} \text{ cut off ratio}$$

$$W_{net} = q_{add} - q_{rej} \left(\frac{kJ}{kg}\right)$$

$$\eta_{th} = \frac{W_{net}}{q_{add}}$$

$$\eta_{th,diesel} = 1 - \frac{1}{r^{\gamma-1}} \left[\frac{r_c^\gamma - 1}{\gamma(r_c - 1)} \right]$$

Prove $\eta_{th} = 1 - \frac{1}{r^{\gamma-1}} \left[\frac{r_c^\gamma - 1}{\gamma(r_c - 1)} \right]$ Diesel

$$\eta_{th} = \frac{W_{net}}{q_{add}} = \frac{q_{add} - q_{rej}}{q_{add}} = 1 - \frac{q_{rej}}{q_{add}}$$

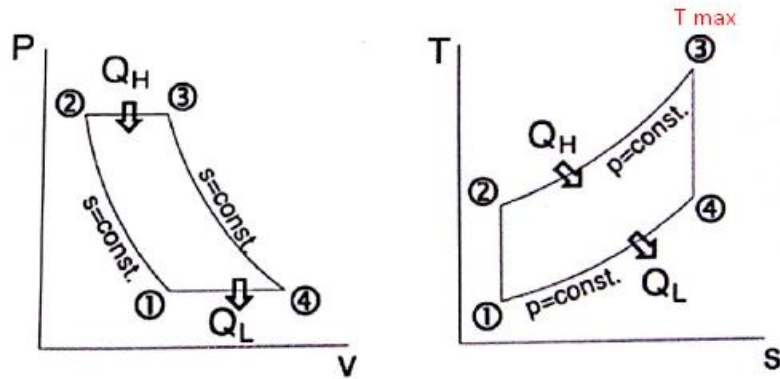
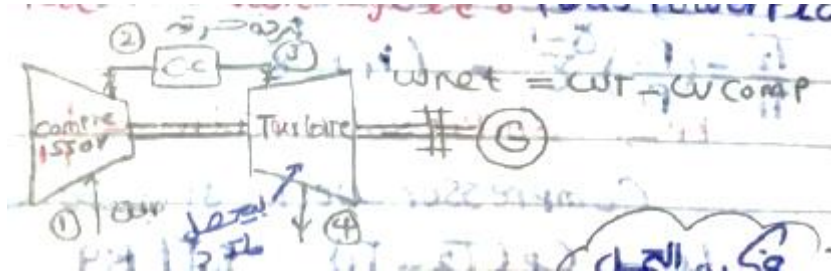
$$\eta_{th} = 1 - \frac{C_v(T_4 - T_1)}{C_p(T_3 - T_2)} \quad \begin{matrix} \text{عالم} \\ \text{مستقر} \\ \text{عالم} \\ \text{مستقر} \end{matrix} \quad \begin{matrix} \text{واقسم} \\ \text{عالم} \\ \text{عالم} \end{matrix}$$

$$= 1 - \frac{\frac{T_1}{T_2} \left(\frac{T_4}{T_1} - 1 \right)}{\frac{C_p}{C_v} \left(\frac{T_3}{T_2} - 1 \right)}$$

$$\frac{T_4}{T_1} = \frac{T_4}{T_3} \cdot \frac{T_3}{T_2} = \left(\frac{V_3}{V_4} \right)^{\gamma-1} \cdot \frac{V_3}{V_2} \left(\frac{V_1}{V_2} \right)^{\gamma-1} = \left(\frac{V_3}{V_2} \right)^{\gamma-1} \cdot \left(\frac{V_3}{V_2} \right) = r_c^\gamma$$

$$\therefore \frac{T_3}{T_2} = \frac{V_3}{V_2} = r_c, \quad \frac{T_1}{T_2} = \left(\frac{1}{r} \right)^{\gamma-1}$$

(3) Simple Brayton cycle



(1-2) isentropic compression	(2-3) constant pressure heat addition	(3-4) isentropic expansion
$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$ r_p compression ratio $W_c = c_p(T_2 - T_1)$	$Q = m\Delta h \rightarrow q = \Delta h$ $q = C_p(T_3 - T_2)$	$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$ If there is p drop $P_3 = P_2 - \Delta P$ $W_t = C_p(T_3 - T_4)$

$$W_{net} = w_t - w_c \left(\frac{kJ}{kg} \right)$$

$$\eta_{th} = \frac{W_{net}}{Q_{added}} = 1 - \frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$$

$$W_{out} = \frac{W_{net}}{\dot{m}} \left(\frac{\frac{kJ}{kg}}{\frac{kg}{s}} \right)$$

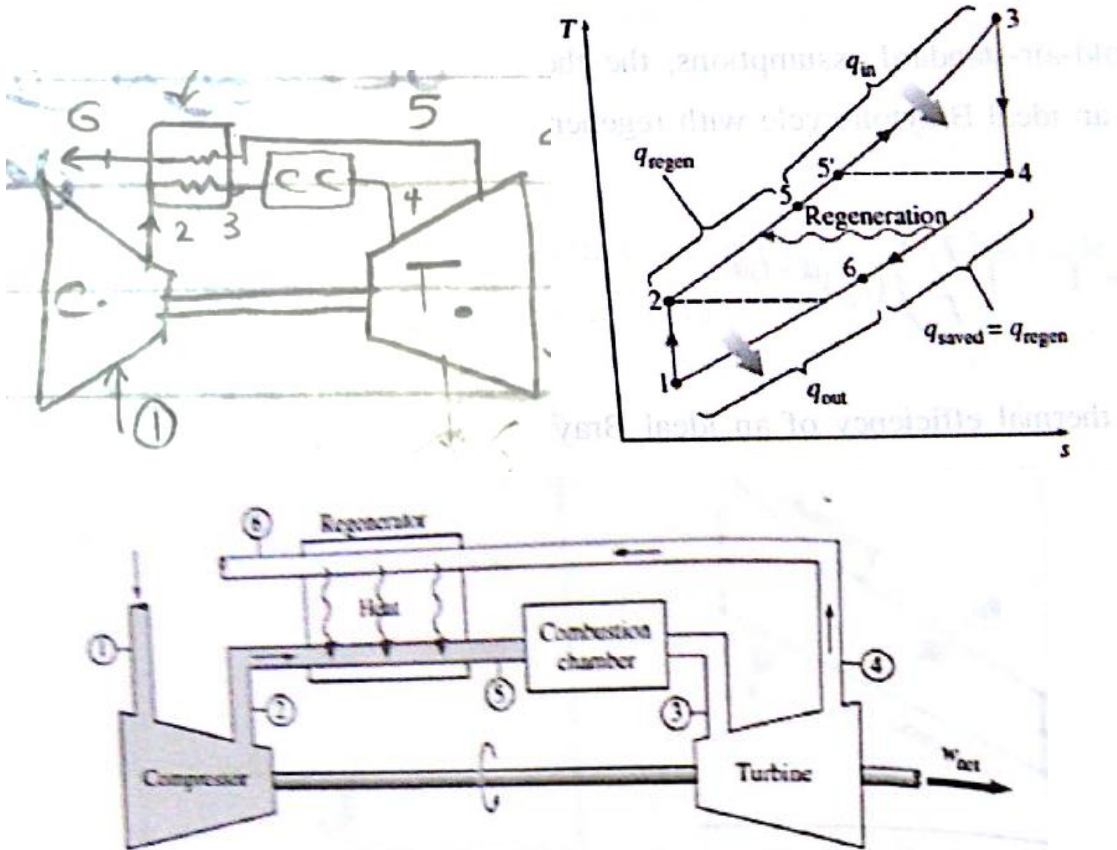
$$BWR \text{ (back work rate)} = \frac{W_c}{W_T}$$

$$r_p = \frac{P_2}{P_1} = \frac{P_3}{P_4}$$

How to increase the Brayton cycle ?

$$\eta_{th} = \frac{w_t \uparrow - w_c \downarrow}{q_{added} \downarrow}$$

1- Brayton Cycle with regeneration $q_{added} \downarrow$



لو حطينا الحراره على 1 على طول هيزيد الحجم وارجع اضغطه تاني في الكومبروسر فهخسر عشان كده بسخن الخرج 2

(1-2) isentropic compression	(5-3) constant pressure heat addition	(3-4) isentropic expansion
$\frac{T_2}{T_1} = r_p^{\frac{\gamma-1}{\gamma}}$ r_p compression ratio $W_c = c_p(T_2 - T_1)$	$Q - m\Delta h \rightarrow q = \Delta h$ $q_{add} = C_p(T_3 - T_5)$	$\frac{T_3}{T_4} = r_p^{\frac{\gamma-1}{\gamma}}$ $\frac{T_3}{T_5} = r_p^{\frac{\gamma-1}{\gamma}}$

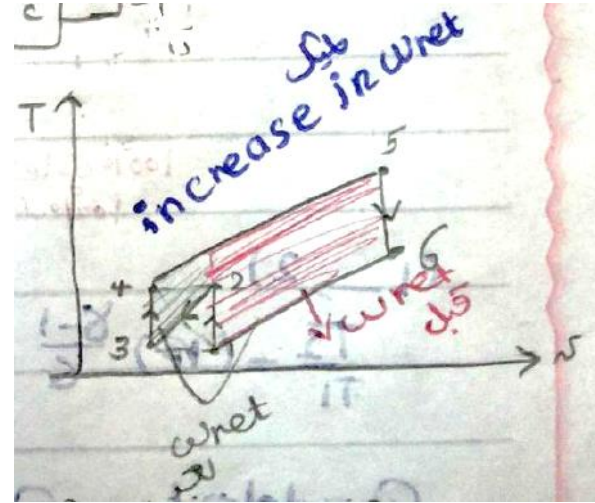
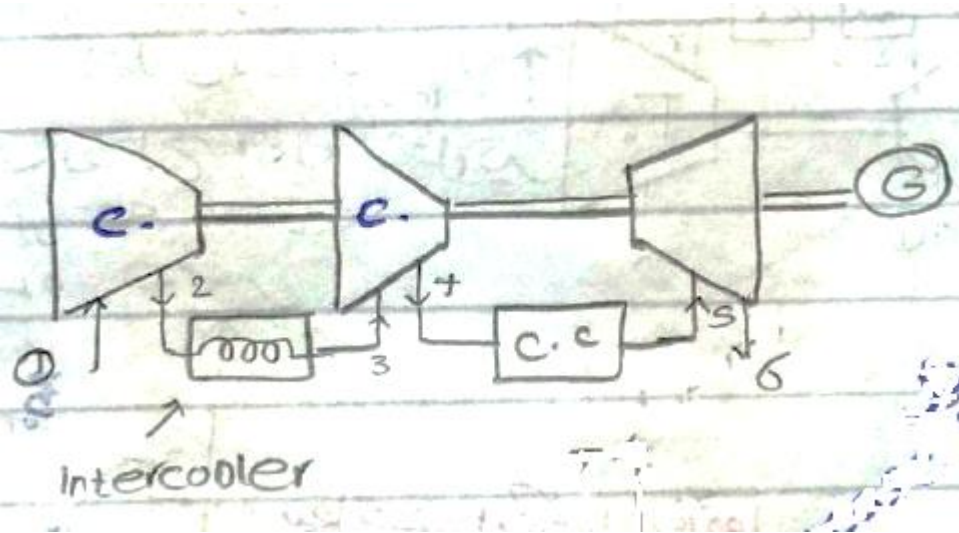
$$W_{net} = W_t - W_c$$

$$Effectiveness (\epsilon) = \frac{\text{actual heat transfer (actual)}}{\text{maximum heat transfer(ideal)}} = \frac{C_p(T_5 - T_2)}{C_p(T_4 - T_2)} = \frac{h_5 - h_2}{h_4 - h_2}$$

perfect if $T_4 = T_5$; $T_2 = T_6$ $\therefore \epsilon = 1$

2- Brayton Cycle with intercooler $W_c \downarrow$

$$W_c = v (v \text{ specific}) \Delta P \quad (\text{depend on } r_p \text{ i can't change it}) = v \downarrow \Delta P$$



2 compressors same r_p for less cost

عيب ان الحرارة الناتجة من ال 2 كومبروسر هتقل فهنحتاج add q اكبر

r_{p_o} overhood pressure ratio

r_p pressure ratio for each state

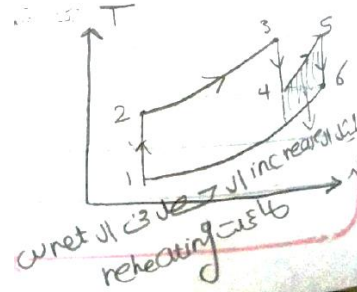
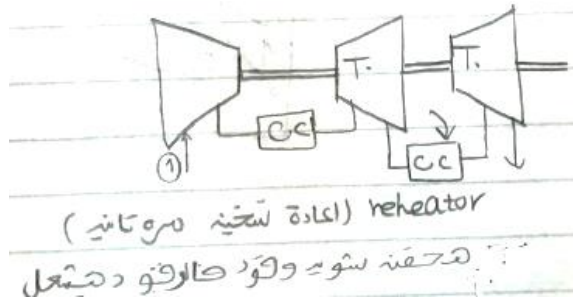
n number of state

$$r_p = \sqrt[n]{r_{p_o}}$$

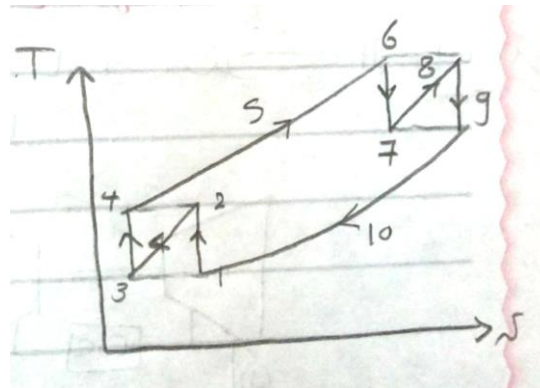
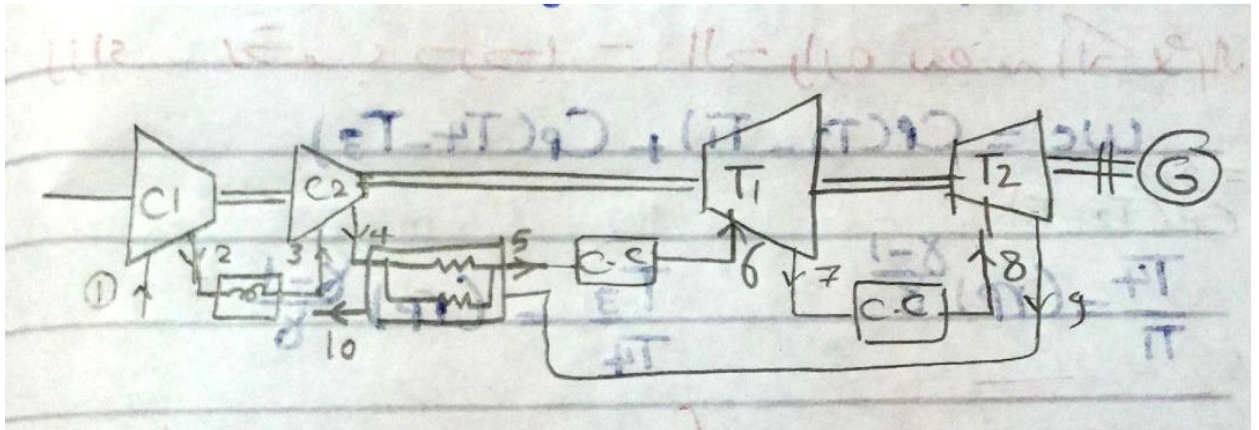
(1-2)(3-4) isentropic compression	(4-5) constant pressure heat addition	(3-4) isentropic expansion
$W_c = C_p(T_2 - T_1) + C_p(T_4 - T_3)$ $\frac{T_4}{T_1} = \left(\frac{P_4}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$ & $\frac{T_3}{T_4} = r_p^{\frac{\gamma-1}{\gamma}}$	$Q - m\Delta h \rightarrow q = \Delta h$ $q_{add} = C_p(T_5 - T_4)$	

$$\text{ideal : } \frac{P_2}{P_1} = \frac{P_4}{P_3} \quad \text{for best performance}$$

3-Brayton Cycle with reheat $q_{add} \downarrow$



Brayton with (Regeneration & intercooling & reheating)

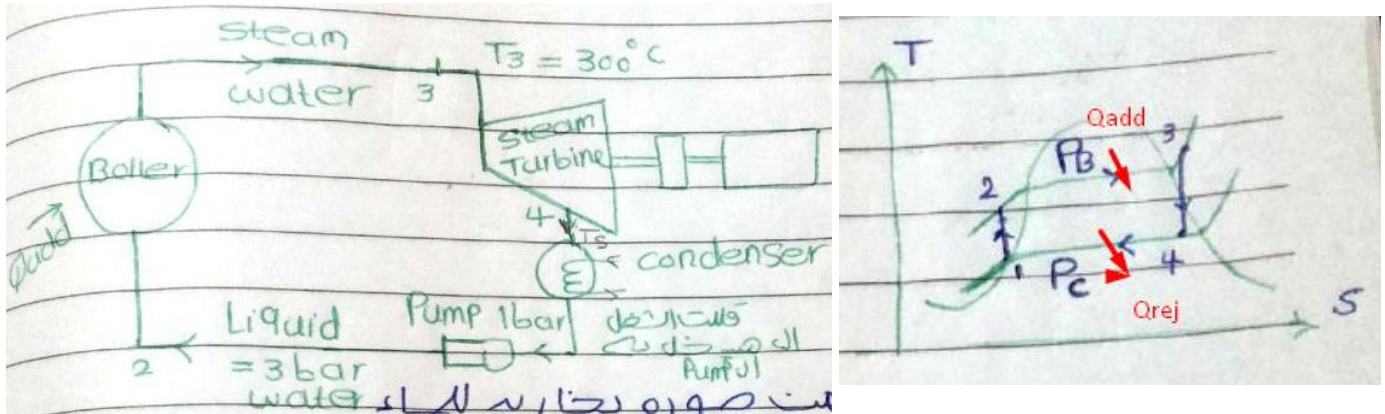


$$\epsilon = \frac{T_5 - T_4}{T_9 - T_4}$$

$$\eta_{th} : 70 \rightarrow 75 \%$$

Steam Power Cycle

(1) Simple Rankine Cycle



$$P_B \text{ (Boiler Pressure) } = P_2 = P_3$$

$$P_C \text{ (Condenser Pressure) } = P_1 = P_4$$

$$P_C \xrightarrow{\text{PUMP}} P_B$$

$$\text{Turbine Work } W_t = h_3 - h_4$$

$$\text{Pump Work } W_p = h_2 - h_1 = v(P_2 - P_1)$$

$$W_{net} = W_t - W_p = q_{in} - q_{out}$$

$$q_{add(in)}(\text{Boiler}) = h_3 - h_2$$

$$q_{out}(\text{Condenser}) = h_4 - h_3$$

$$\eta_{th} = \frac{W_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}}$$

$$W_{output} = \dot{m} W_{net} \text{ (kW)}$$

heat rate : amount of heat supplied to generator to generate 1 kwh

Per unit mass

Given

T_3 $P_3 = P_2 = P_B$ $P_C = P_1 = P_4$

* عند ضغط البخار من جدول $h_f = h_1$ في جدول 2

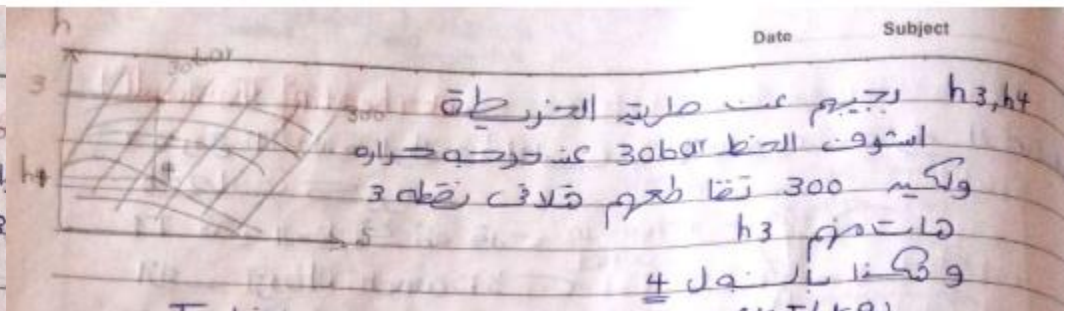
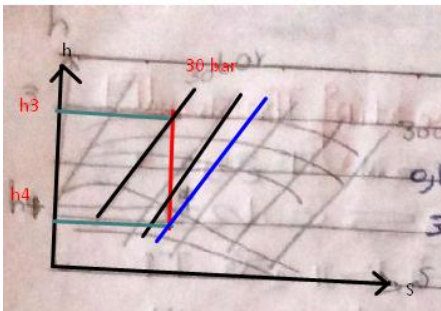
v_1 (specific volume) $v_1 = v_f$

* النقطة 2 في مخطط P - h مضغوطة $\rightarrow$ Compressed Liquid

مفترضة $\rightarrow$ Pump $\rightarrow$ ضغط $\rightarrow$ Liquid $\rightarrow$ زيادة في الحرارة $\rightarrow$ Flow work

$$h_2 = h_1 + \text{Flow work} = h_1 + v_f(P_2 - P_1)$$

$\frac{m}{kg}$ kPa
 $\checkmark$ KJ/kg



To increase Efficiency

1- Lowering The condenser Pressure

Advantage :

Increase in the area of the curve which mean increase in W_{net}

(2- 2') is increase in Q_{in} but it's very small

$\eta \uparrow$

Disatvantage :

- 1- Air leakage into the condenser
- 2- Increase in moisture content at the end of turbine causes corrosion in turbine blades $\times$ (quality) $\downarrow$

Notes : $P \uparrow T \uparrow @$ which Q_{rej} يجب ان يكون الضغط الجديد اكبر من ضغط التشبع

المناظر لدرجه حرارة

التبريد

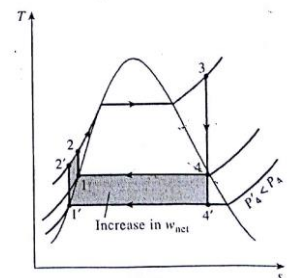


FIGURE 10-6
The effect of lowering the condenser pressure on the ideal Rankine cycle.

2- Superheating the steam to high temperatures

Advantage :

1- increase in area in $W_{net} >$ increase in Q_{add}

Then $\eta \uparrow$

2- Less moisture content x (quality) $\uparrow$

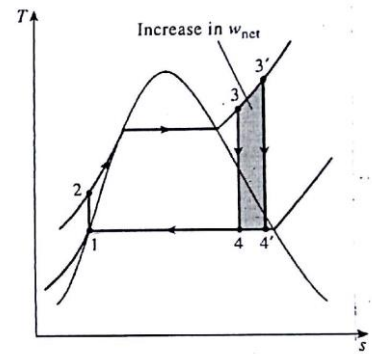


FIGURE 10-7

The effect of superheating the steam to higher temperatures on the ideal Rankine cycle.

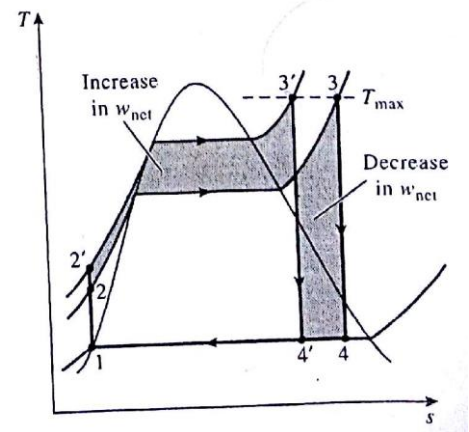
3- Increasing the boiler pressure

we increase temperature by increase boiler pressure
so $\eta \uparrow$ at same turbine T in

disadvantage

$x \downarrow$ at turbine out

solution : reheat to steam



THE IDEAL REHEAT RANKINE CYCLE

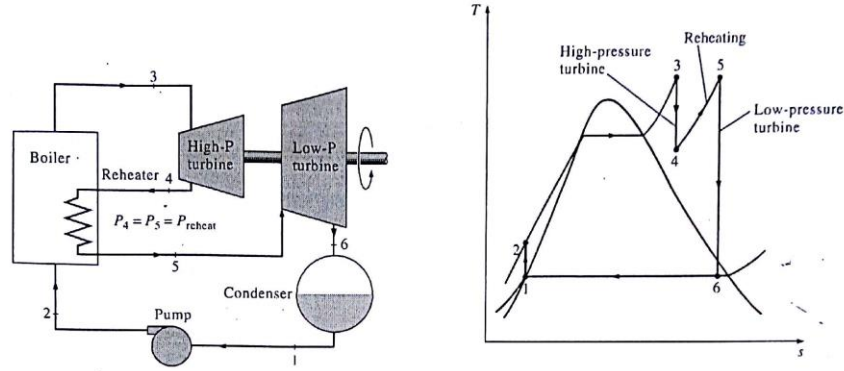


FIGURE 10-11

The ideal reheat Rankine cycle.

الهدف : تقليل ال Moisture content

الحل : 1- تحميم البخار ولكن ليها Limit وهي درجة تحمل ريش التربينه

2-نقسم التربينه لمرحلتين HPT وثم reheat ثم LPT

مرحلة ال HPT من 3 الي 4 (يتمدد البخار و يصل لضغط متوسط)

مرحلة reheat يعيد رفع درجة حراره البخار الي T5 (غالبا T3=T5)

مرحلة LPT يتمدد البخار حتي يصل لضغط المكثف

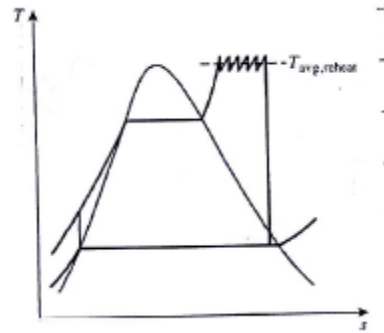
ملاحظات :

1- طريقه ال reheat تحسن كفاءه الدوره بمقدار 4% الي 5% عن طريق زياده Tavg التي يتم عندها اضافته حراره للبخار

2- افضل ضغط نعمل عنده reheat هو ربع ضغط البويلر $P_{reheat} = \frac{1}{4} P_{boiler}$

3- عند زياده مرحله ثانيه يكون التحسن (نصف) التحسن من المرحلة الواحده

4- عند زياده مراحل ال reheat تكون عمليا تمدد و reheat قريبه من isothermal process



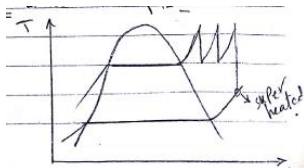
5- اذا كان ضغط التربينه غير مرتفع عند عمل double reheat سينتج بخار محمص وهذا ليس جيد لان

عندها يتم طرد الحراره عند درجه حراره عاليه مما يقلل من كفاءه

الدوره

الحل / لا نعمل double reheat الا عند ضغوط اكبر من

super critical pressure $P > 22.06 \text{ MPA}$



THE IDEAL REGENERATIVE RANKINE CYCLE

إضافة الماء من 2 إلى 2' هو اضافته حراره عن درجات حراره منخفضه
مما يقلل T_{av} التي يتم عندها اضافته درجه الحراره (مشكله)
الحل : نسخن ال feed water الماء الخارج من المضخه

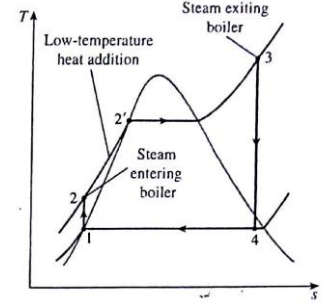


FIGURE 10-14

The first part of the heat-addition process in the boiler takes place at relatively low temperatures.

إذا استخدمنا مبادل حراري داخل التربينه لعمل ذلك الحل فان ذلك يؤدي الي زياده محتوى الرطوبه مما يضر بريش التربينه

الحل : نعمل bleeding لجزء من البخار من التربينه ندخله على مبادل حراري

feed water heater او regenerator

مزايا ال Regenerator

- 1- تحسين كفاءه الدورة
- 2- تعدد وسيله لعمل Dearthation لل feed water : أي التخلص من الهواء المتسرب داخل المكثف
- 3- يساعد على التحكم في حجم البخار الكبير في المرحله الاخير للتربينه (الضغط بيقبل ف الحجم بيزيد)

1- Open Feed water heaters (Direct Contact)

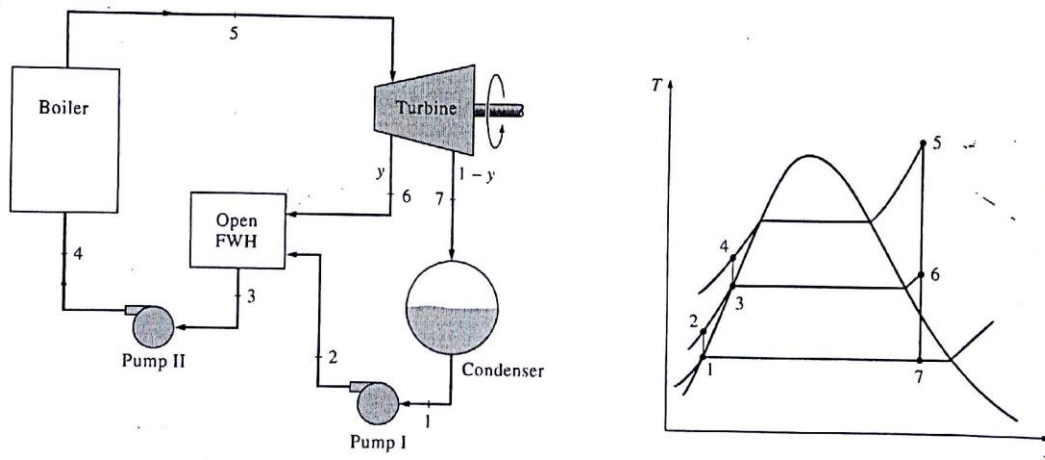
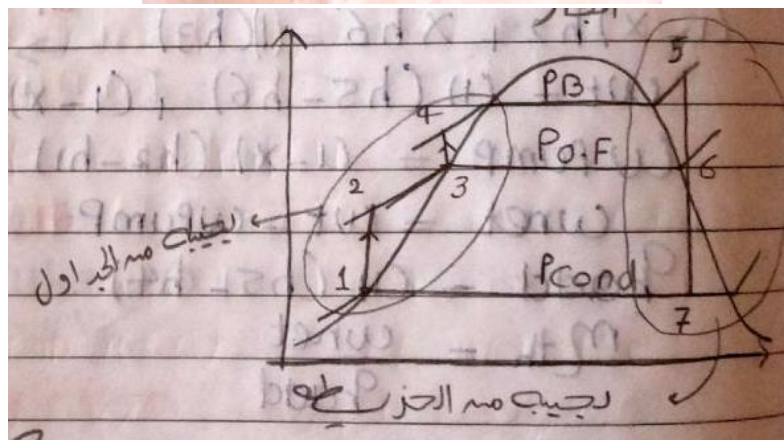
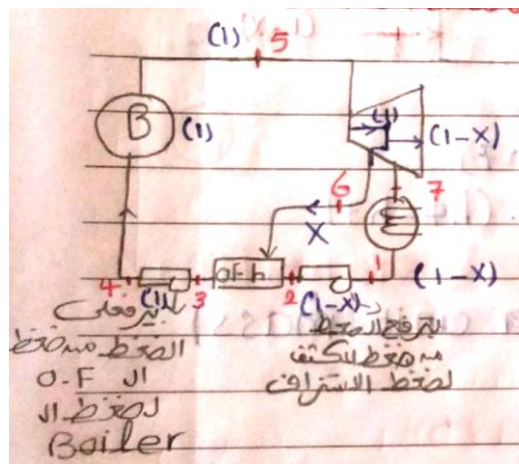


FIGURE 10-15

The ideal regenerative Rankine cycle with an open feedwater heater.

For 1 kg of steam



Open FWH

هي غرفة خليط بين البخار المستخرج من التربة و الماء الخارج من المضخة

في الحالة المثالية يترك الخليط في هذه الغرفة عن ضغط اضافته الحرار ويكون saturated liquid

- يدخل البخار إلى التوربين عند النقطة (5) ويتدفق مع شوت الإنتروبي Isentropically إلى نقطة (6). نقوم باستنتاج هبوط البخار "steam" من هذه النقطة ويتم توصيله إلى غرفة الخلط حيث نقوم بتسخين Feed water في حوض يستقبل باقى البخار المتدفق من التوربين مع شوت الإنتروبي حيث يصل إلى النقطة (7) ويقلل الكثافة ثم يخرج ماء مشبع (saturated liquid) عند النقطة (1).
ثم يتم ضغط الماء من النقطة Isentropically من (1) إلى (2) ثم إلى Feed water heater حيث يتم خلطه مع البخار المسحوب من التوربين حيث يخرج الخليط ماء مشبع عند النقطة (3) saturated liquid.

ثم يدخل الماء مشبع إلى غرفة التسخين حيث يتم ضغطه Isentropically من النقطة (3) إلى (4) ثم تكتمل الدورة بواسطة التبريد مع شوت الإنتروبي داخل الفلاليق من النقطة (4) إلى (5).

* ملاحظة

تزداد الكفاءة أكثر بزيادة عدد Feed water heater ولكن أقل راحة عدد
مع هذه المبادئ الحرارية. يعتمد على الاعتبارات الاقتصادية.

ملامح ضغط البخار Liquid هذا نقطة في كل دورة في كل دورة إلى 7 ج
- دائرة استرخاء O.F.w.h
قالب ال Qadd
قالب ال mass, Florate
ازى احبب X ازاد احبب Mth
① احبب كذا لى (7) h(1→7)
Given Pc Ps, Ts
P3 = P6

From Table (2) at $P_1 = P_2 = V$

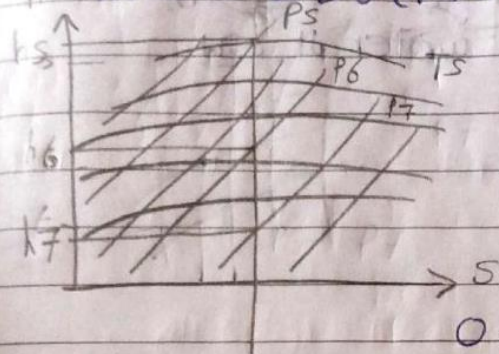
$$h_1 = h_f = V, \quad v_1 = v_f$$

$$h_2 - h_1 = v_1 (P_2 - P_1) \rightarrow h_2 = V$$

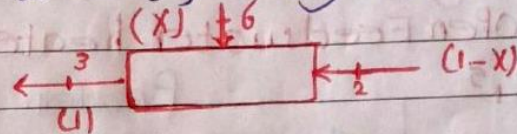
From Table at $P_3 = V$

$$h_3 = h_f, \quad v_3 = v_f$$

$$h_4 - h_3 = v_3 (P_4 - P_3)$$



مقدار انتران = واری ال O.F



$$(1-x)h_2 + xh_6 = (1)h_3 \rightarrow x = V$$

$$w_t = (1)(h_5 - h_6) + (1-x)(h_6 - h_7)$$

$$w_{\text{pump}} = (1-x)(h_2 - h_1) + (1)(h_4 - h_3)$$

$$w_{\text{net}} = w_t - w_{\text{pump}}$$

$$q_{\text{add}} = (1)(h_5 - h_4) \quad (\text{per unit mass})$$

$$\eta_{\text{th}} = \frac{w_{\text{net}}}{q_{\text{add}}}$$

Turbine ← سبب البخار ال استند في

ال (1) د أنما الفرق في ال

2- Closed Feed water heaters

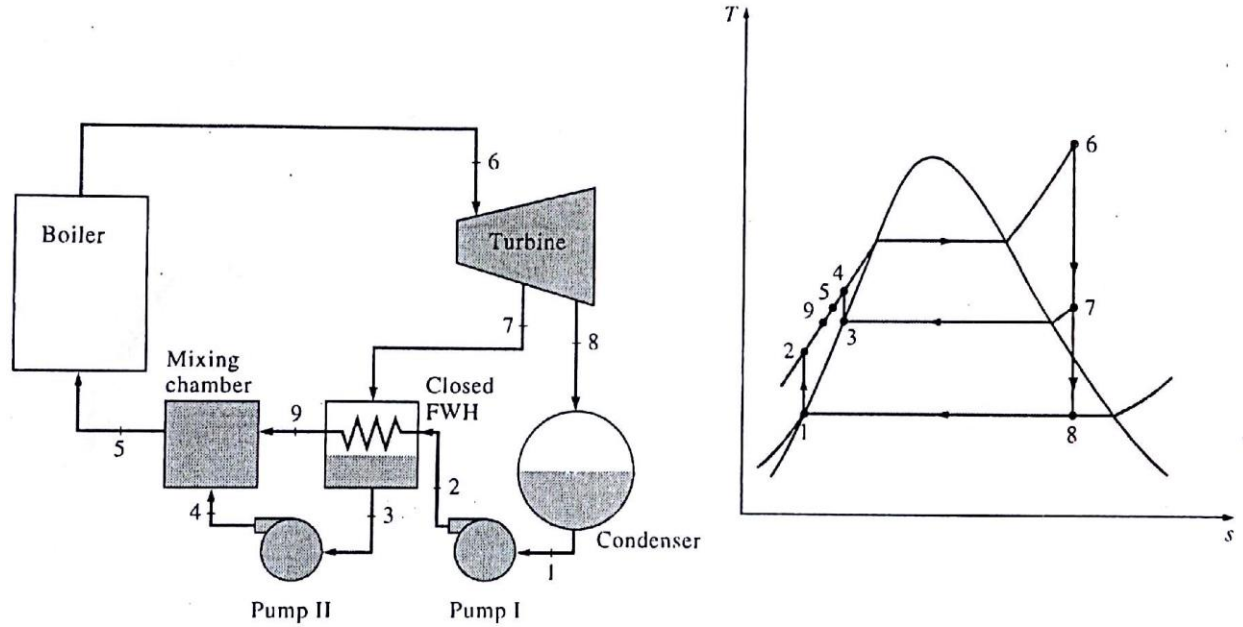


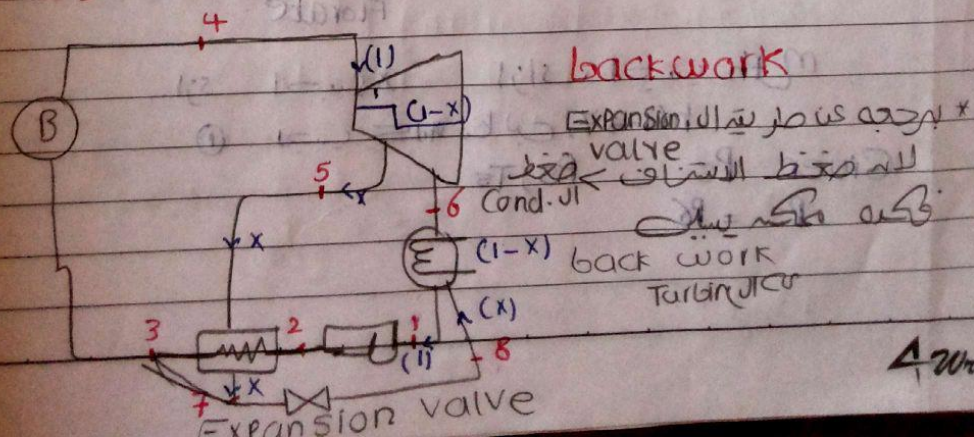
FIGURE 10-16

The ideal regenerative Rankine cycle with a closed feedwater heater.

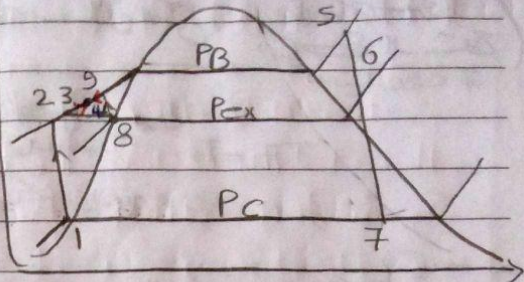
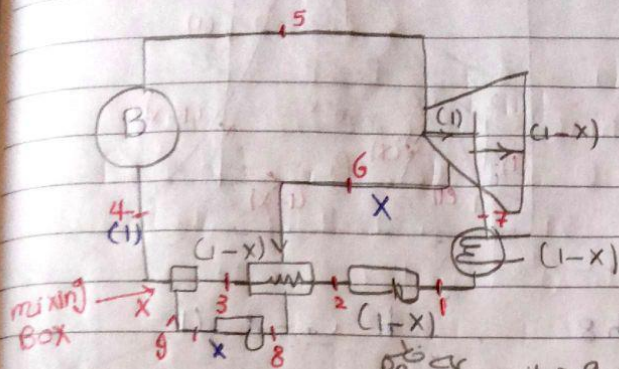
يتم انتقال الحرارة بين الماء المسحوب من التربينات و الماء الخارج من المضخة دون خلط بينهما لذا من الممكن ان يكون كل من الاثنين لهما ضغط مختلف عن الآخر

من الحالة التالية: يتم تسخين الماء الخارج من المضخة عند نقطة (2) بحيث يخرج من الجدران الحرارية
 closed feed water heater (بدرجة حرارة تساوي درجة حرارة الجدران) ليقاد من التربينات
 من الجدران الحرارية أي أن (3) و (4) وتكون نقطة (3) ماء سابع

(2) closed feed water heater:



closed (Forward)



8- انتاج ال Pump متوقف من 8 ← 9 و 9 > ال هو PB^{cr}

* خط 3: أجيب انقده 4/ 4 واقفه 4

heat balance C.F.W.H

$$(1-x)h_2 + xh_6 = x(h_8) + (1-x)h_3$$

X 555

heat balance also for mixing box

$$\text{inPut} = \text{outPut}$$

$$(1-x)h_3 + xh_9 = (1)h_4 \rightarrow \text{c.w. } h_4$$